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The biomass production and nutrient content of roselle leaves grown with poultry litter and Organosuper®

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ABSTRACT. The objective of this study was to evaluate the effects of poultry litter and Organosuper® with three modes of application on the biomass production and nutrient content of the leaves of roselle plants. The treatments in each crop cycle were in a factorial arrangement, 2 x 3 + 1, composed of a control and combinations of the two organic fertilizers (poultry litter (10 ton. ha^{-1}) and Organosuper® (10 ton. ha^{-1}) and the three application modes (surface, incorporated and surface + incorporated), in a randomized block design with four replicates. In the surface + incorporated mode, the organic fertilizers were applied as 5 ton. ha^{-1} surface and 5 ton. ha^{-1} incorporated. The highest productions of fresh and dry weight and number of calyxes were obtained for poultry litter in surface (10,776, 1,239 and 3,980,602 kg ha^{-1}, respectively) and Organosuper® incorporated (11,372, 1,308 and 4,405,075 kg ha^{-1}, respectively) in the agricultural year 2009/2010. The increases in the fresh and dry weights of the calyxes, leaves, stems and roots, number of calyxes, leaf area and fibers in the agricultural year 2008/2009 in the poultry litter treatments. Nutrients concentrations in the dry weight of the roselle leaves were not affected by the organic fertilizer type or by the mode of application.

Keywords: *Hibiscus sabdariffa*, organic fertilizer, surface, incorporated.

Produção de biomassa e teor de nutrientes em folhas de rosela cultivada com cama-de-frango e Organosuper®

RESUMO. O objetivo deste trabalho foi avaliar o efeito da cama-de-frango e do Organosuper® sob três modos de aplicação na produção de biomassa e nos teores de nutrientes nas folhas de plantas de rosela. Os tratamentos em cada ciclo de cultivo foram arranjados como fatorial 2 x 3 + 1, sendo constituídos pelas combinações de dois compostos orgânicos cama-de-frango (10 t ha^{-1}) e Organosuper® (10 t ha^{-1}) e três modos de aplicação (cobertura, incorporada e cobertura + incorporada) mais a testemunha, no delineamento experimental de blocos casualizados, com quatro repetições. As maiores produções de massas frescas e secas de cálices e o número de cálices foram obtidos para cama-de-frango em cobertura (10.776, 1.239 e 3.980.602 kg ha^{-1}, respectivamente) e Organosuper® incorporado (11.372, 1.308 e 4.405.075 kg ha^{-1}, respectivamente) no ano agrícola 2009/2010. As maiores produções de massas frescas e secas de cálices, folhas, caules e raízes, número de cálices, área foliar e fibras no ano agrícola 2008/2009 foram obtidas com a cama-de-frango. Os teores de nutrientes não foram influenciados pelos resíduos orgânicos nem pelo modo de aplicação.

Palavras-chave: *Hibiscus sabdariffa*, resíduo orgânico, cobertura, incorporado.

Introduction

The roselle plant (*Hibiscus sabdariffa* L., Malvaceae) is originally from India, Sudan and Malaysia and has been introduced to eastern Africa and Central America. In Brazil, it has adapted to several regions and can also be found in residential gardens. Its leaves and fruits are widely used for human and animal food, and the stems are a source of fiber for the textile and paper industries. The roselle plant is an important source of the vitamins A, B and C, iron, phosphorus and protein; it can be used as are placement for animal protein. Its calyx is used in jelly, paste, sweets, syrup and wine preparation; its manufacturing residues can also produce high quality vinegar (CHANG et al., 2003; FAGBENRO, 2005; MUKHTAR, 2007; OTTAI et al., 2006).

In highly weathered tropical soils, organic matter is of great importance for providing nutrients to crops, the retention of cations, the complexation of toxic elements and micronutrients (FRANCHINI et al., 2001; SIQUEIRA NETO et al., 2009), structural stability (SALTON et al., 2008), infiltration and water retention, aeration and microbial activity; thus, organic matter content constitutes a fundamental component of the productive capacity of soil. To provide nutrients for plants, the organic matter added to the soil must be decomposed by soil microorganisms, and the nutrients within organic molecules must be released (mineralized). This mineralization process is influenced by the quantity and quality of the organic material and the environmental conditions, including temperature, moisture, aeration and acidity (RASSE et al., 2005).

Management practices can affect various soil properties, such as the organic matter content, pH and water availability, in addition to affecting the rate of the decomposition of the organic matter because the management affects the size of the particles of organic matter and their location in the soil (surface or incorporated). In addition, nitrogen availability for decomposition can locally limit the population and activity of the microbial decomposers because of insufficient contact of the organic matter with the soil (GIACOMINI et al., 2008; POTTHOFF et al., 2005).

Poultry litter is a low cost organic waste that has been widely used to supply the nutrients required by plants because of its chemical composition (SANTOS et al., 2004). It is primarily composed of sawdust and rice hulls, but the contents may vary depending on the handling, feed composition and waste of the bird feeders and drinkers. The Brazilian broiler production system allows the reuse of litter in one to eight lots. Thus, attention should be paid to the quality of the litter used in order to achieve the goal of the replenishment of nutrients in the soil (RAMOS et al., 2011). According to producers, each broiler generates 3.4 kg of litter as waste during eight cycles of 45 to 60 days each.

Organosuper® is a multi-nutrient organic material that is produced using a unique bioextraction technique. The composting formula, completedafter approximately 15 days, generates temperatures up to 100 degrees for an uninterrupted period of more than 24 hours, ensuring the sterility of the product, which is free of pathogens, seeds and other waste that is undesirable for fertilization. The Organoeste units of Dourados, Mato Grosso do Sul State, and Andradina, São Paulo State, recently received both national and international certification for their products by ECOCERT BRAZIL, which governs the certification of organic products, and by the COFRAC French National Agency, according to ISO 65 Guide and based on the 007/99 Normative Instruction of the Ministry of Agriculture, Livestock and Food Supply (MAPA).

Thus, the objective of this study was to evaluate the effects of poultry litter and Organosuper® with three modes of application on the biomass production and nutrient content of the leaves of roselle plants.

Material and methods

At the Medicinal Plant Nursery (MPN) of the Federal University of Grande Dourados (UFGD) in Dourados, Mato Grosso do Sul State, two experiments were performed with roselle: one in the agricultural year of 2008/2009 and another in 2009/2010. This area is located in the southern part of Mato Grosso do Sul State at an average altitude of 452 m and at 22°14’16” S latitude and 54°49’2” W longitude. The climate is Cwa, by the Köppen classification system. The soil, originally from Cerrado vegetation, is classified as distroferric Red Latosol, with a sandy, heavy texture and flat topography.

The treatments in each crop cycle were in a factorial arrangement, 2 x 3 + 1, composed of a control and combinations of the two organic fertilizers (poultry litter (10 ton. ha^{-1}) and Organosuper® (10 ton. ha-1) and the three application modes (surface, incorporated and surface + incorporated), in a randomized block design with four replicates. In the surface + incorporatedmode, the organic fertilizers were applied as 5 ton. ha^{-1} surface and 5 ton. ha^{-1} incorporated. To compare the control withthe poultry litter and Organosuper®, the following contrasts were performed: C_1 = (incorporated poultry litter + poultry litter on the surface + poultry litter incorporated/surface)/3 – control and C_2 = (incorporated organosuper + organosuper on the surface + organosuper incorporated/surface)/3 – control.

The total area of the plots was 6.0 m^2 (1.5 m of width x 4.0 m of length) with a useful area of 4.0 m^2 (1.0 m of width and 4.0 m of length). The plants were grown in double rows in the plots, with spacing of 0.80 m between the plants and 0.70 m between the rows, totaling 16,666 plants ha^{-1}. Two lines of plants with the same spacing were cultured around the entire experiment as a borderline buffer.

The propagations were by indirect sowing and were begun on 12.14.2008 and 11.20.2009 for the agricultural years 2008/2009 and 2009/2010, respectively, with harvested seeds of cultivated plants from the MPN, UFGD. The seedlings were grown in polystyrene trays of 128 cells with Plantmax® substrate; they were kept in a protected environment with 50% Sombrite® and received daily irrigation. When the seedlings were approximately 10 cm in height, they were transplanted to the soil plots on 01.24.2009 and 12.27.2009 for the agricultural years 2008/2009 and 2009/2010, respectively.

The soil was prepared a week before the transplant by plowing, harrowing and the elevation of the plots with two passes of a bed shaper off set rotary cultivator. On the second pass of the implement, the poultry litter and Organosuper® were incorporated at different doses; immediately after the transplant, the poultry litter and Organosuper® were scattered on the surface of the appropriate plots. Lime was not used as a soil amendment during the crop cycle, nor any other fertilization technique.

When the plants started flowering at 89 and 95 days after transplant (DAT) for agricultural years 2008/2009 and 2009/2010, respectively, four plants were harvested from each plot, pulling the entire plant. Then, the stems and the leaves were separated to determine the leaf area and the fresh and dry weights. The calyxes from the remaining plants from each plot were harvested on two days, at 119 and 158 DAT for the agricultural year 2008/2009 and 139 and 185 DAT for the agricultural year 2009/2010; only calyxes that were greater 3.5 cm were harvested. The harvesting was done manually using pruning shears to cut the stems just below the calyx. The calyxes were counted and weighed, and after the last harvest, the number and fresh weight were totaled.

To obtain the dry weight, the weighed calyxes, leaves, stems and roots were cut and distributed separately in paper bags. The bags were put into an oven with forced air circulation at a temperature of 60°C ± 5°C and dried until a constant weight was achieved.

The phosphorus (P) concentrations of the dried leaves and calyxes were determined using the colorimetric molybdovanadate method; the potassium (K) concentrations were determined by flame photometry, and the calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn), concentrations by atomic absorption spectrometry. To determine the total nitrogen (N) concentrations, the samples were subjected to sulfuric digestion and then N concentrations were measured by Kjeldahl distillation (MALAVOLTA et al., 1997). The percentage of crude fiber in the stems was determined using the methodology described by AOAC (1995), and the amount of crude fiber was estimated in kg ha^{-1} using the expression: (% fiber x fresh weight of stems)/100.

Individual and combined variance analysis was completed for each measurement. A Tukey test was applied at 5% probability to compare the means, and Dunnett's test was used to compare each treatment with the control. At test was used for comparison of the contrasts. Analysis of contrasts was performed to separate specific treatments, and the trends and stability of these contrasts were also evaluated. All statistical analysis was completed using SAEG (RIBEIRO JUNIOR; MELO, 2009).

Results and discussion

The conjoint variance analysis of the experiments showed that there was a significant interaction between treatment and years for the fresh and dry weight of the leaves, stems, roots and calyxes, the number of calyxes, the leaf area and the fiber; therefore, individual analyses were performed for these experimental variables. For N, P, K, Ca, Mg, Fe, Cu, Mn and Zn concentrations, there was no significant interaction; for that reason, the comparisons between organic fertilizer type, mode of application and control were made using the average of the two years for the conjoint analysis of the experiments.

Variations in production between years are expected in upland conditions due to the rainfall variability (BLAISE, 2006). Lower rainfalls were observed in March (70 mm), April (0 mm) and May (49 mm) for the year 2008/2009, than in March (125 mm), April (56 mm) and May (169 mm) of the agricultural year 2009/2010. It is likely thatthe higher rainfall and better rain fall distribution of the agricultural year 2009/2010 were responsible for the higher fresh and dry weights of the calyxes, leaves and stems, higher numbers of calyxes and higher leaf area for that year. Environmental variability may prevent the phenotypic realization of the potential of a genotype (BRADOW; DAVIDONIS, 2000).

The fresh and dry weight and the number of calyxes were significantly influenced by the interaction between the organic fertilizer type and the mode of application in the agricultural year 2009/2010, with the highest production for poultry litter on the surface and for Organosuper® incorporated into the soil, which were not statistically different from the incorporated/surface application mode (Table 1).

Table 1. Fresh and dry weight of calyx and calyxes number of roselle plants grown under two sources of organic fertilizer and three application modes in the agricultural year 2009/2010. City of Dourados – UFGD.

Organicfertilizer	Fresh weight of calyx (kg ha^{-1})		
	Incorporated	surface	Inc.+ Sur.
Poultrylitter	8,136 aA	10,776 bB	9,648 aAB
Organosuper®	11,372 bB	7,245 aA	10,768 aB
	Dry weight of calyx (kg ha^{-1})		
Poultrylitter	936 aA	1,239 bB	1,110 aAB
Organosuper®	1,308 bB	833 aA	1,238 aB
	Calyxes number (million ha^{-1})		
Poultrylitter	3,176,509 aA	3,980,602 bB	3,770,169 aAB
Organosuper®	4,405,075 bB	2,627,561 aA	4,205,940 aB

Means followed by the same lowercase in columns and capital letters in the lines, for each feature, do not differ by Tukey and F tests, respectively, at 5% probability.

The fresh and dry weight of the calyxes and the number of calyxes were greater than in the controls for all treatments except for Organosuper® on the surface in the year 2009/2010 (Table 2). These results suggest that the organic fertilizers provided organic mineral products, including P and K, through increased soil microbial activity. Changes can occur in the aeration and the water holding capacity of soil in response to organic decomposition, (HEREDIA ZÁRATE et al., 2003), favoring the growth and development of plants.

Table 2. Fresh and dry weight of leaves, stems, roots and calyx, calyxes number, leaf area and fibers in the stem of roselle plants grown under two sources of organic fertilizer and three application modes plus control, in the agricultural years 2008/2009 and 2009/2010. City of Dourados - UFGD.

Organic fertilizer	Application mode	Fresh weight of leaf (kg ha^{-1})		Dry weight of leaf (kg ha^{-1})	
		2008/2009	2009/2010	2008/2009	2009/2010
Control		7,581 a	11,962 a	1,115 a	1,760 a
	Incorporated	13,013 b	20,222 b	1,915 b	2,976 b
Poultry litter	surface	12,270 b	20,013 b	1,806 b	2,945 b
	Inc. + Sur.	11,692 b	17,879 b	1,721 b	2,631 b
	Incorporated	8,744 a	19,956 b	1,287 a	2,937 b
Organosuper®	surface	8,321 a	19,397 b	1,224 a	2,855 b
	Inc. + Sur.	9,603 b	17,553 b	1,413 b	2,583 b
C.V. (%)		11.16	8.48	11.16	8.48
		Fresh weight of stem (kg ha^{-1})		Dry weight of stem (kg ha^{-1})	
Control		16,306 a	14,128 a	2,969 a	2,572 a
	Incorporated	30,185 b	29,018 b	5,496 b	5,283 b
Poultry litter	surface	28,349 b	26,969 b	5,162 b	4,910 b
	Inc. + Sur.	27,777 b	23,537 b	5,057 b	4,285 b
	Incorporated	19,690 a	25,632 b	3,585 a	4,667 b
Organosuper®	surface	18,323 a	25,877 b	3,336 a	4,711 b
	Inc. + Sur.	20,970 b	22,601 b	3,818 b	4,115 b
C.V. (%)		11.24	12.62	11.23	12.60
		Fresh weight of root (kg ha^{-1})		Dry weight of root (kg ha^{-1})	
Control		1,185 a	727 a	363 a	216 a
	Incorporated	2,038 b	959 a	531 b	285 a
Poultry litter	surface	2,023 b	1,003 b	567 b	298 b
	Inc. + Sur.	1,890 b	1,045 b	517 b	311 b
	Incorporated	1,360 a	1,122 b	412 a	333 b
Organosuper®	surface	1,197 a	1,020 b	358 a	303 b
	Inc. + Sur.	1,467 a	1,049 b	500 b	312 b
C.V. (%)		10.59	14.54	11.45	14.54
		Fresh weight of calyx (kg ha^{-1})		Dry weight of calyx (kg ha^{-1})	
Control		3,427 a	5,780 a	394 a	664 a
	Incorporated	3,914 a	8,088 b	438 a	930 b
Poultry litter	surface	4,730 a	10,306 b	529 a	1,185 b
	Inc. + Sur.	5,464 b	9,648 b	612 b	1,109 b
	Incorporated	2,908 a	11,372 b	334 a	1,307 b
Organosuper®	Surface	3,132 a	6,741 a	360 a	775 a
	Inc. + Sur.	3,046 a	10,768 b	350 a	1,238 b
C.V. (%)		24.24	9.83	24.07	9.82
		Number of calyxes (million ha^{-1})		Leaf area (cm^2)	
Control		4,148,874 a	4,225,269 a	9,853 a	15,580 a
	Incorporated	4,198,683 a	4,317,650 b	15,575 b	23,242 b
Poultry litter	surface	4,203,127 a	4,398,060 b	15,526 b	25,074 b
	Inc. + Sur.	4,246,364 b	4,377,016 b	14,795 b	22,711 b
	Incorporated	4,129,709 a	4,440,507 b	11,385 a	25,220 b
Organosuper®	Surface	4,131,653 a	4,262,756 a	10,682 a	23,500 b
	Inc. + Sur.	4,141,652 a	4,420,594 b	12,152 a	22,122 b
C.V. (%)		22.15	10.97	10.60	10.14
		Fiber (kg ha^{-1})			
Control		678 a	155 a		
	Incorporated	1,255 b	286 b		
Poultry litter	surface	1,179 b	269 b		
	Inc. + Sur.	1,155 b	263 b		
	Incorporated	819 a	187 a		
Organosuper®	Surface	762 a	174 a		
	Inc. + Sur.	872 b	199 b		
C.V. (%)		11.24	19.28		

Means followed by at least one same letter in each column do not differ at 5% probability by Dunnett test.

The fresh and dry weight production of the leaves of the roselle plants were greater than in the control for all treatments, except for Organosuper® incorporated or on the surface in the agricultural year 2008/2009 (Table 2). The fresh and dry weight production of the leaves were 27.88 and 27.89%, respectively, and were higher for plants grown in soil with poultry litter compared with those grown in soil with Organosuper® in the agricultural year 2008/2009 (Table 3). Contrast 1 showed that the poultry litter increased the fresh weight of the leaves for agricultural years 2008/2009 and 2009/2010, respectively, by 4,744 and 7,409 kg ha^{-1}, and by 698 and 1,091 kg ha^{-1} for the dry weight of leaves. However, contrast 2 showed that Organosuper® increased the fresh and dry weight production of the leaves by 7,006 and 1,031 kg ha^{-1} for the agricultural year 2009/2010 only (Table 3). In contrast, the fresh and dry weight of leaves was not influenced significantly by the modes of application of the organic fertilizers (Table 4).

The fresh and dry weight of the stems from roselle plants of all treatments, except for Organosuper® incorporated or on the surface in the agricultural year 2008/2009, were higher than the control (Table 2). The fresh and dry weights of the stems were, respectively, 31.66 and 31.65% higher in the plants grown in soil with poultry litter than in those grown in the soil with Organosuper® in the agricultural year 2008/2009 (Table 3). Contrast 1 showed that the poultry litter increased the fresh weight of the stems for agricultural years 2008/2009 and 2009/2010, respectively, by 12,464 and 12,379 kg ha^{-1} and increased the dry weight by 2,269 and 2,254 kg ha^{-1}. For Organosuper®, contrast 2 showed increases in fresh weight of stems for the agricultural years 2008/2009 and 2009/2010, respectively, of 3,354 and 10,575 kg ha^{-1} and increases in the dry weight of 611 and 1,925 kg ha^{-1}. However, the fresh and dry weight productions of the stems were not significantly affected by the modes of application of the organic fertilizers (Table 4).

Table 3. Fresh and dry weight of leaves, stems, roots and calyx, calyxes number, leaf area, fiber content on stem and nitrogen content of leaves of roselle plants grown under two sources of organic fertilizers, in the agricultural years 2008/2009 and 2009/2010. City of Dourados – UFGD.

Organic fertilizer	Fresh weight of leaf (kg ha^{-1})		Dry weight of leaf (kg ha^{-1})	
	2008/2009	2009/2010	2008/2009	2009/2010
Poultry litter (pl)	12,325 a	19,371 a	1,814 a	2,851 a
Organosuper®	8,889 b	18,968 a	1,308 b	2,792 a
Control	7,581	11,962	1,116	1,760
C_1 = pl - control	4,744*	7,409*	698*	1,091*
C_2 = or - control	1,309ns	7,006*	193ns	1,031*
	Fresh weight of stem (kg ha^{-1})		Dry weight of stem (kg ha^{-1})	
Poultry litter (pl)	28,771 a	26,508 a	5,238 a	4,826 a
Organosuper®	19,661 b	24,703 a	3,580 b	4,498 a
Control	16,307	14,128	2,969	2,572
C_1 = pl - control	12,464*	12,379*	2,269*	2,254*
C_2 = or - control	3,354*	10,575*	611*	1,925*
	Fresh weight of root (kg ha^{-1})		Dry weight of root (kg ha^{-1})	
Poultry litter (pl)	1,983 a	1,003 a	538 a	298 a
Organosuper®	1,341 b	1,064 a	423 b	316 a
Control	1,188	727	363	216
C_1 = pl - control	798*	276*	176*	82*
C_2 = or - control	156ns	337*	61ns	100*
	Leaf area (cm^2 $plant^{-1}$)		Fibers (kg ha^{-1})	
Poultry litter (pl)	15,299 a	23,676 a	1,197 a	1,019 a
Organosuper®	11,406 b	23,614 a	818 b	1,004 a
Control	9,853	15,580	678	635
C_1 = pl - control	5,446*	8,096*	519*	384ns
C_2 = or - control	1,553ns	8,035*	140*	369*
	Fresh weight of calyx (kg ha^{-1})		Dry weight of calyxes (kg ha^{-1})	
Poultry litter (pl)	4,703 a	-	527 a	-
Organosuper®	3,029 b	-	348 b	-
Control	3,427	-	394	-
C_1 = pl - control	1,276	-	133	-
C_2 = or - control	-398	-	-46	-
	Calyxes number (million ha^{-1})			
Poultry litter (pl)	2,160586 a	-		
Organosuper®	1,343384 b	-		
Control	1488740	-		
C_1 = pl - control	671,846	-		
C_2 = or - control	-145,356	-		

Means followed by at least one same letter in each column do not differ at 5% probability by the F test. *, ns: contrasts significant and no significant, respectively, at 5% probability by t test.

Table 4. Fresh and dry weight of leaves, stems, roots and calyx, calyxes number, leaf area, fiber in the stem and nitrogen content of leaves of roselle plants grown under three application modes in the agricultural years 2008/2009 and 2009/2010. City of Dourados – UFGD.

Application mode	Fresh weight of leaf (kg ha^{-1})		Dry weight of leaf (kg ha^{-1})	
	2008/2009	2009/2010	2008/2009	2009/2010
Incorporated	10,878 a	20,089 a	1,601 a	2,956 a
Surface	10,296 a	19,705 a	1,515 a	2,900 a
Inc. + Sur.	10,648 a	17,716 a	1,567 a	2,607 a
	Fresh weight of stem (kg ha^{-1})		Dry weight of stem (kg ha^{-1})	
Incorporated	24,938 a	27,325 a	4,540 a	4,975 a
Surface	23,336 a	26,423 a	4,249 a	4,811 a
Inc. + Sur.	24,373 a	23,069 a	4,437 a	4,200 a
	Fresh weight of root (kg ha^{-1})		Dry weight of root (kg ha^{-1})	
Incorporated	1,699 a	1,041 a	471 a	309 a
Surface	1,610 a	1,012 a	463 a	301 a
Inc. + Sur.	1,678 a	1,047 a	508 a	311 a
	Fresh weight of calyx (kg ha^{-1})		Dry weight of calyx (kg ha^{-1})	
Incorporated	3,412 a	-	386 a	-
Surface	3,932 a	-	445 a	-
Inc. + Sur.	4,255 a	-	481 a	-
	Calyxes number (million ha^{-1})		Leaf area (cm^{2}plant^{-1})	
Incorporated	1641965 a	-	13,480 a	24,231 a
Surface	1673907 a	-	13,104 a	24,287 a
Inc. + Sur.	1940084 a	-	13,473 a	22,416 a
	Fibers (kg ha^{-1})			
Incorporated	1,037 a	1,062 a		
Surface	970 a	1,013 a		
Inc. + Sur.	1,014 a	959 a		

Means followed by at least one same letter in each column do not differ in the level of 5% probability by Tukey test.

The fresh and dry weights of the roots of the roselle plants for all treatments were greater than in the control, except for Organosuper® incorporated or on the surface in the agricultural year 2008/2009 (Table 2). In the agricultural year 2008/2009,the fresh and dry weight production of the roots were, respectively, 32.38 and 21.38% higher in plants grown in soil with poultry litter than in those grown in soil with Organosuper® (Table 3).Contrast 1 showed that the poultry litter increased the fresh weight of the roots for agricultural years 2008/2009 and 2009/2010, respectively, by 798 and 276 kg ha^{-1} and the dry weight of the roots by 176 and 82 kg ha^{-1}. However, contrast 2 showed that the Organosuper® resulted in increases in the fresh and dry weight of the roots by 337 and 100 kg ha^{-1} for the agricultural year 2009/2010 only. As for the leaves and stems, the fresh and dry weight of the roots was not affected significantly by the mode of application of the organic fertilizers (Table 4).

The leaf areas of the roselle plants were greater than in the control for the poultry litter incorporated, poultry litter on the surface and poultry litter incorporated + on the surface treatments in the agricultural year 2008/2009 and for all of the treatments in the agricultural year 2009/2010 (Table 2). The leaf areas for plants grown in soil with poultry litter in the agricultural years 2008/2009 and 2009/2010 were, respectively, 35.59 and 33.97% higher than those grown in soil with Organosuper® (Table 3). Contrast 1suggested that the poultry litter increased the leaf area by 5,446 and 8,096 cm^2 for the agricultural years 2008/2009 and 2009/2010, respectively; however, contrast 2 suggested that Organosuper® increased the leaf area by 8,035 cm^2 for the agricultural year 2009/2010 only. Moreover, the leaf area was not influenced significantly by the mode of application of the organic fertilizers (Table 4).

The fiber production of the roselle plants in all treatments was higher than the control, except for Organosuper® incorporated or on the surface in the agricultural years 2008/2009 and 2009/2010 (Table 2). In the agricultural year 2008/2009, the fiber production of plants grown in soil with poultry litter was 31.66% higher than in those grown in soil with Organosuper® (Table 3). Contrast 1 suggested that the poultry litter increased fiber production by 519 kg ha^{-1} of fiber in the agricultural year 2008/2009. Contrast 2 showed that Organosuper® increased fiber production by 140 and 369 kg ha^{-1} of fiber for the agricultural years 2008/2009 and 2009/2010, respectively. However, fiber production was not significantly influenced by the mode of application of the organic fertilizers (Table 4).

The increases in the fresh and dry weights of the calyxes, leaves, stems and roots, number of calyxes, leaf area and fibers in the agricultural year 2008/2009 in the poultry litter treatments are likely because of improvement in the soil physical properties, an increase in the water retention in the soil and water availability to plants (KARAMANOS et al., 2004) and increases in soil nutrients (BLAISE, 2006). Poultry litter likely provided high concentrations of N, P and K in the soil solution for plant growth and development; the poultry litter used in the agricultural year 2008/2009 had higher concentrations of these nutrients (3.15, 3.07 and 0.85% of N, P and K, respectively) than that used in the agricultural year 2009/2010 (2.52, 1.07 and 0.18% of N, P and K, respectively). Singh et al. (2006) reported that an increase in the supply of P results in higher concentrations of free and bound inorganic solutes. The combined effects of better nutrition and water availability in the plots with poultry litter resulted in higher yields. Furthermore, in rain fed areas of the tropics with high temperatures and evaporation, the addition of poultry litter allows better retention of soil moisture for long periods of irregularly distributed rainfall.

The mode of application of the organic fertilizers had no statistically significant effects on any of the characteristics evaluated in the two agricultural years, except for the fresh and dry weight of calyxes and the number of calyxes for the agricultural year 2009/2010. The degree of contact required for the decomposition of organic matter depends mainly on the C:N ratio of the organic material added to soil (RECOUS et al., 1995). With lower N levels (high C:N) in the organic matter, the influence of these two factors on the decomposition rate in the soil will be higher because the contact with the organic matter regulates the availability of the soil N to the microorganisms involved in decomposition. The degree of contact controls the flow of water and nutrients, especially NO_3, from the soil to the sites of organic matter decomposition (GIACOMINI et al., 2008). Therefore, one can assume that because the C:N ratios of both the poultry litter and Organosuper® are low (7.64 and 8.75 for poultry litter in the years of 2008/2009 and 2009/2010, respectively, and 7.57 for Organosuper®), decomposition was not favored by incorporating the fertilizer into the soil. It is likely that the N concentration present in the organic matter supplied the N demand of the microorganisms active in the decomposition of the carbonaceous constituents. In addition, the N from the mineralization of the soil organic matter may have also contributed to meeting the microbial need for this nutrient.

The nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) concentrations in the dry weight of the roselle leaves were not affected by the organic fertilizer type or by the mode of application, with mean concentrations of 38.69, 0.90, 1.94, 12.88, 3.10 g kg^{-1}; 1,694.00, 15.63, 346.35 and 21.97 mg kg^{-1}, respectively.

Conclusion

Under the conditions studied, it was concluded that roselle plants must be cultivated in soil fertilized with chicken manure, independent of the mode of application, to increase the fresh and dry weight of calyxes, leaves, stems and roots, the number of calyxes, the leaf area and the fibers.

The nutrient concentrations were not affected by the organic fertilizer type or by the mode of application.

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